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NEW METHODS FOR NONLINEAR TRACKING AND NONLINEAR CHAOTIC SIGNAL PROCESSING

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New Methods for Nonlinear Tracking and Nonlinear Chaotic Signal Processing

In our previous report, we demonstrated our ability to identify the sources making up a given signal via nonlinear signal processing. During the current period, we made comparisons with conventional techniques, both from a theoretical viewpoint and by example.

Most conventional signal identification techniques rely on identifying features in the various correlation functions and their Fourier transforms. The simplest procedure is just to look for features in the spectrum.

When that is not sufficient, one can proceed to examine the higher order correlation functions (three- and four-point functions) and their Fourier transforms (bi-spectra, etc.). It is useful to understand that these two-, three-, and four-point time averages and their transforms are just low-order moments of an underlying density function. For linear processes and weakly nonlinear ones, that is essentially all of the available information. However, if there are significantly nonlinearly generated signals present it is better to look for features in the densities themselves rather than in moments of the densities.

A very important additional advantage in working directly with the densities is that the Fourier transform of the densities (the characteristic functional) factors into a product of terms, one for each independent signal contained in the composite signal. The analogous result for two- and three-point functions is that the spectra separate into a sum of independent spectra. For higher moments, beginning with the fourth, the relationship is not simple, and nonlinear processing must be done.

Once nonlinear processing must be done, it then appears to be more useful to compare densities rather than moments and look for features in the densities. One can then take advantage of the factorization property of the characteristic functional.

During the past month we attempted to separate the signals that we described last month by looking directly at the spectra. That procedure turns out to be a useful tool for rejection rather than acceptance. Several of the possibilities could be eliminated without further processing. However, the remaining set of candidates required other kinds of processing. Thus, the second-order moments are a useful tool for preliminary processing. We performed some simple tests with third-order moments and found them to be marginally useful. Some additional preliminary rejection can be done, but identification was not possible.

Fourth-order moments already require nonlinear processing, and since they tend to average over features rather than accentuate them we have not yet tested their usefulness as a rejection mechanism. Except for cases where the signals are weakly nonlinear, we do not expect enough gain to compensate for the additional computations required.

Thus, we conclude that conventional signal-processing techniques that identify features in the low-order spectra are useful as a preliminary rejection technique but are far from being able to identify correctly the number of composite signals.

We have thus far compared densities by considering a simple time lag and computing two-dimensional densities (the second-order moment of such a density is the correlation function evaluated at the time lag). The square of the difference of a candidate density and the given density is then summed over the density. This simple figure of merit was sufficient to distinguish different densities. Note that there are usually some significant features in the density plots and it might prove useful to identify such features. Because of the factorization into different signal pieces, it is probably better to look directly at the Fourier transform of the density.

In recent years, there has begun to be some interest in extracting density features, although mostly in one dimension. A monograph entitled "Density Estimation," by B.W Silverman, discusses the current state of the art, which is still rather primitive. One of the more promising methods goes by the catchy title "Projection Pursuit." It attempts to identify regions of the density plot that have significant features. The theoretical development of this technique appears to be still in an early stage.

We also tried several examples of combinations of three signals and were successful in identifying the components. Details will be presented in the final report. We also computed densities for different time lags. There is much additional information to be gained by considering several time lags. As we pointed out earlier, the correlation function is just the second moment of a density, and if we only considered a single time lag for a correlation function we wouldn't have any of the important spectral information.

In summary, we have verified that the procedure for separating signals works, and it now remains to improve the efficiency and decide on the best search strategy.